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OIDIUM OR POWDERY MILDEW OF THE VINE

By FREDERIC T. BIOLETTI

EFFECT OF OIDIUM ON YOUNG GROWTH.

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OIDIUM OR POWDERY MILDEW OF THE VINE.

Fungous Diseases of the Vine. California is peculiarly fortunate in its freedom from most of the serious fungous vine diseases which add so much to the expense and uncertainty of grape growing in most countries. Peronospora, Black Rot, and Anthracnose are here quite unknown. Of the four most serious fungous diseases which attack the above-ground portions of the vine, these three are the most to be feared, as they are not only capable, if neglected, of destroying the whole crop of a vineyard, but require the utmost vigilance and much troublesome treatment with winter washes and summer sprays to hold them in check. Their absence makes quite unnecessary the swabbing of the dormant vines with sulfate of iron and the spraying of the growing vines with Bordeaux mixture which are adopted here by some vineyardists who have learned the practice in Europe or the Eastern States where it is necessary.

On the other hand, the remaining serious fungous disease—Oidium —exists in all parts of California. From one point of view, this is the most serious disease of the four, as, if uncontrolled, it is capable of spreading more universally through the vineyards and of absolutely destroying the crops in nearly all. From another point of view, it is the least to be feared, as it is possible to control it completely, at least in most parts of California, by much simpler and less expensive methods than are needed for the others mentioned.

Introduction of Oidium into Europe. With the exception of Anthracnose, which is a native of Europe, all these diseases originated on the wild vines of the Eastern and Central parts of the United States. Peronospora and Black Rot are comparatively recent introductions into Europe. The former was observed for the first time in 1878, the latter not until 1885. The Oidium was first noted in Europe about 1845, when an English gardener named Tucker found it in graperies at Margate, near the mouth of the Thames. It was discovered two years later in the hot-houses of Paris and Belgium.

Severity of the Disease in Europe. From this time it spread rapidly, until by 1851 it had reached every grape-growing country of Europe. The amount of injury done by the disease was enormous and increased every year, reaching its maximum in France about 1854. In

this year it reduced the crop of grapes in France over 75 per cent., in many districts totally destroying the crop.

Discovery of the Utility of Sulfur. After 1854, the grape growers of France commenced to learn how to control the disease. The use of sulfur for this purpose, discovered and perfected between 1850 and 1853, soon became general, and by 1859 the crop of grapes had reached its normal volume in France. The effect of Oidium in diminishing the crop and the effect of sulfur in controlling the disease in one department of France is well shown by fig. 1. This figure, which is adapted from one published in the nursery catalogue of F. Richter, Montpellier, indicates also the destruction of French vineyards by Phylloxera and their rehabilitation by means of resistant vines. The rapidity with which sulfur enabled the French grape growers to reëstablish their vineyards is in contrast with the slower process of controlling the phylloxera. In three or four years after the use of sulfur became general in the Herault the crops had reached their normal volume. It has taken twenty years to reëstablish the same vineyards on phylloxera resistant stocks.

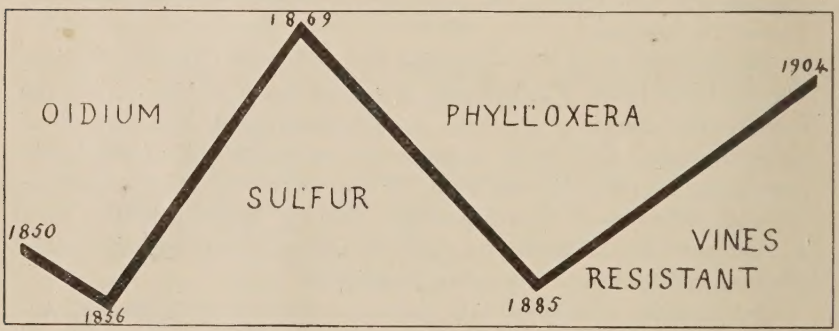


Fig. 1. Showing (1) the reduction of crop of wine in the Herault from 3,900,000 hectoliters in 1850 to 1,000,000 hectoliters in 1856 by the attack of Oidium; (2) the rapid increase of crop after the general use of sulfur; (3) the reduction by phylloxera of the crop from 15,200,000 hectos in 1869 to 2,100,000 hectos in 1885; and (4) the gradual increase due to the use of resistant vines.

Damage done by the Disease in California. In California the Oidium has never produced such wide-spread and serious injury as that indicated above. This arises principally from the dryness and heat of the atmosphere during summer in most of our grape-growing regions. The dryness of our climate is undoubtedly the cause of our

immunity to Peronospora, Anthracnose, and Black Rot, and while Oidium requires less moisture than these diseases for its development, it spreads more rapidly and is more difficult to control in a moist atmosphere than in a dry one.

At the same time, the Oidium does far more harm, even in California, than is usually suspected, and in certain regions and certain seasons may totally destroy the crop and diminish the crops of following years by injuring the vine.

There has been a recrudescence of the intensity of this disease both in Europe and California during the last few years. This is due in all probability not to any change in the fungus or of the seasons, as has been suggested, but to the neglect of regular sulfuring by the grape growers, who have become careless after years of comparative immunity due to more or less general treatment for the disease.

While most grape growers in California sulfur their vines in some way, many of them do not succeed in completely controlling the disease and are often doubtful of the utility of the treatment. Where good sulfur does not give immunity it is because it has not been applied in the *right way* or at the *right time*. Many growers who do succeed in keeping their vines free from Oidium do so at the expense of far more sulfur and labor than are necessary.

The main object of this bulletin, therefore, is to point out the methods of control which have been generally found the best and least costly.

DESCRIPTION OF THE DISEASE.

Relationships of the Disease. This disease, usually called *Mildew* in California, is caused by a fungus belonging to the same group as the fungi which cause the mildews of roses, hops, beans, and apples and is generally referred to as *Oidium* in Europe. The disease known as *Mildew* or *Peronospora* in Europe and the East is totally different and caused by a fungus of very different character. In order to distinguish the two, the *Oidium* is sometimes called *Powdery Mildew* and the *Peronospora, Downy Mildew*. As only one exists in California, the use of the word Mildew should lead to no confusion, though perhaps it is best to adopt Oidium as the name of this disease.

Symptoms and Effect on the Vine. The Oidium attacks all herbaceous parts of the vine,—leaves, canes, flowers, and fruit. In the spring, the young leaves which are attacked show at first whitish patches about one-quarter of an inch in diameter on the upper or lower surfaces. (See fig. 2.)

As the disease progresses these patches run together until a large part of the surface of the leaf may be covered with a grayish white mildew. The leaf ceases to grow and curls up towards its upper surface. (See figure on cover.)

Fig. 2. White patches of Oidium on upper surface of young leaf.

As the shoots lengthen, the canes may be attacked in the same way. The patches of mildew appear usually near the bases of the canes and are difficult to see until they acquire the gray tint. In severe cases, the fungus may completely cover the whole surface of the cane, but it is usually confined to patches. If these patches are rubbed the fungus comes off completely. The places where it has been, however, will turn dark later owing to injuries to the superficial cells of the bark. (See fig. 3.)

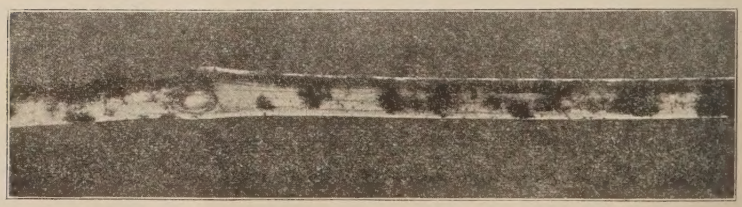


Fig. 3. Blackening of canes due to Oidium.

These marks, at first brown, later black, are usually branching or fern-like in form, showing the points of attack of the fungus. If the canes are attacked when young, they fail to mature properly and often turn black over their whole surface. It is this form of Oidium which has sometimes been mistaken for Anthracnose in California.

Later, the blossoms and fruit may be attacked. When the blossoms are attacked they fail to set, and if the berries are attacked when very small, they will fail to develop and will drop off. If the fruit reaches nearly full size before being affected, it continues to develop, but irregularly. The parts of the epidermis injured by the fungus become hardened and cease to grow. This results in irregularity in the form of the berry and in severe cases in cracking. (See fig. 4.)

Fig. 4. Berries badly affected and cracked. (After Foëx.)

If this cracking occurs early, the grapes dry up completely before ripening. If later, they may develop sugar and can be used for wine making, but the crop is diminished in volume. In moist seasons the berries which are cracked usually become the prey of blue mould and are completely destroyed.

After the grapes have lost the green color due to the presence of chlorophyll in the skin and have commenced to ripen they are not attacked by Oidium. The markings and blotches which are often seen on ripe grapes are due to injuries to the skin caused by the presence of the fungus on the grapes before they ripened. If the attack has not been early or serious enough to prevent the grapes reaching normal

size they may still make good wine. The markings, however, are very objectionable on table and raisin grapes and decrease their value.

Tokay and Muscat grapes often show the dark, fern-like markings characteristic of the disease similar to those shown on the canes. (See fig. 3.) When abundant, these markings, which are accompanied by a thickening of the skin, injure the appearance of the raisins. Where the skin of the Muscat grape has been attacked by Oidium it will remain smooth after drying and not show the fine wrinkling characteristic of the finest raisins.

A vine of which the leaves are badly attacked has a peculiar color and wilted appearance. (See figure on cover.) This appearance is only shown when the conditions of temperature and moisture are favorable to the growth of the fungus on the exterior leaves. This can occur only at the beginning of the season in the warmer and drier parts of the State. When the air is hot and dry the fungus cannot grow on the outer leaves. The proper favorable conditions, however, may still exist in the interior of the vine. For this reason vines may look perfectly healthy from a little distance, while the fruit and the bases of the canes may be covered with Oidium. A vine which is badly attacked has a moldy smell readily perceptible to many people.

DESCRIPTION OF THE FUNGUS.

Mode of Attack. The botanical name of the fungus is *Uncinula spiralis* (Berkeley and Cooke), and it belongs to the family or group of Erysipheae. All the members of this family are parasites which live upon the outer surfaces of leaves and other green organs of plants. The white "*mildew*" which they form on these surfaces consists of the branching threads or *mycelium,* which constitute the vegetative body of the fungus. This *mycelium* grows only on the surface, unlike the *mycelia* of *Peronospora* and other parasitic fungi which enter the tissues of the host plant. It obtains its nourishment from the epidermal cells of the plant attacked, by means of suckers—*haustoria*—which penetrate these outer cells. The outer cells thus attacked become dark colored. The fact that the Oidium does not penetrate the tissues of the vine much facilitates its control and renders its destruction possible at any stage without injury to the host plant from the remedies applied.

Summer Form of the Fungus. The mycelial threads of the *Uncinula spiralis* are extremely fine—not over two ten-thousandths of an inch in diameter. They elongate and grow over the surface to which they are attached by their *haustoria* and at intervals send out upright branches—*hyphae*—thirty to forty ten-thousands of an inch long.

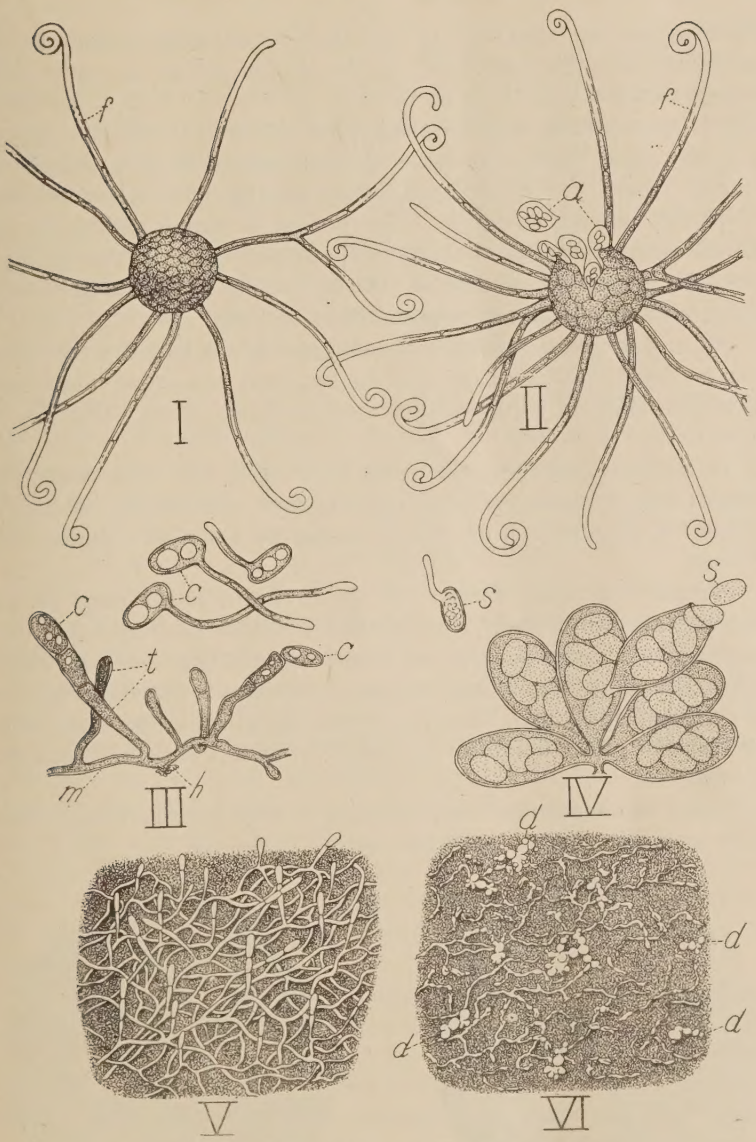


Fig. 5. Various forms of Uncinula spiralis.

I, II. *Perithecia* showing *f, appendages,* and *a, asci.*

III. Summer form showing *m, mycelium; t, hyphae; c, conidia;* and *h, haustoria.*

IV. Group of *asci* removed from *perithecium* emitting *s, ascospores.* (III and IV, after Viala.)

V. Summer form of *Oidium* as it appears on surface of leaf.

VI. Ditto showing effect of *sulfur* (*d*). (V and VI, after Marès.)

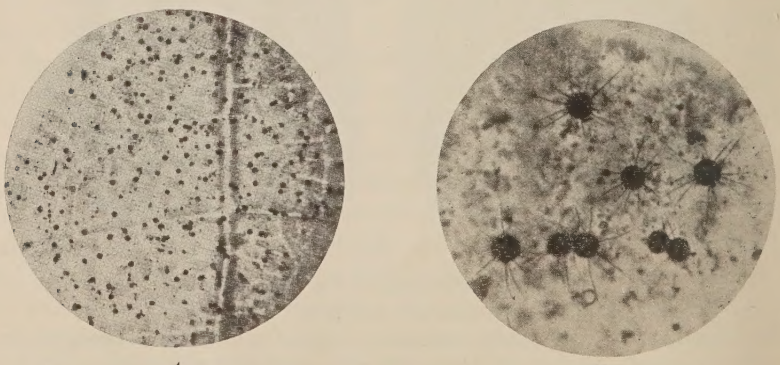
These hyphae are somewhat thicker than the mycelial threads, gradually increasing in diameter from the bottom to the top until they become two or three times as thick as the threads from which they arise. Cross partitions divide the hyphae into several cells, the uppermost of which finally becomes detached and forms a conidium or summer spore. The hypha continues to grow and the second cell develops into another conidium. This process continues as long as the conditions are favorable throughout the summer, each hypha producing a large number of *conidia*. These conidia are egg-shaped and measure about 5 × 12 ten-thousandths of an inch.

When a conidium falls on a suitable part of the vine it sends out a germinating tube which fixes itself by haustoria and grows into a new mycelium which in turn produces more summer spores. (See fig. 5, IIIc.)

In this way, all the green parts of a whole vine may finally be covered with a coating of mycellium, hyphae, and conidia, which together form the whitish or grayish matter we know as *"Mildew"* or *Oidium*.

Winter or Resting Forms. In the autumn another form of the fungus is often produced. Among the felted threads of the mycelium may be seen with the unaided eye numerous round black bodies, which are *perithecia*, or receptacles containing the spores. These bodies have an average diameter of about $\frac{1}{250}$ of an inch, which is about one-third the diameter of the dot of an i in the print of this bulletin. (See fig. 6, *A*, *B*.)

Under the microscope they are seen to vary in color from yellow when unripe to nearly black when mature. (See fig. 7.)



A *B*

Fig. 6. Photomicrographs of *Perithecia* on Surface of Leaf.
A. Magnified 8 times. *B*. Magnified 35 times.

A mature *perithecium* consists of a nearly spherical case containing from four to eight cell-sacks called *asci*. The walls of this case are strong and resistant to cold and other unfavorable conditions which destroy the summer forms of the fungus. They are made up of thick polygonal cells and form a very efficient protection to the asci. An ascus contains from four to six spores. (See figs. 8 and 5, IV.)

Each *perithecium* is furnished with 10 to 25 hair-like appendages of about the same thickness as the mycelial threads and from one-one hundredths to one-fiftieth of an inch in length. These appendages are divided by several cross partitions and are coiled at the free end. They consist usually of a single thread, but occasionally branch. (See fig. 5, II.)

The perithecia remain upon the canes and leaves or in the soil until the return of warm weather in spring. As soon as the temperature becomes sufficiently high, the walls of the perithecia break open and allow the asci to emit their spores. These spores, when they reach a leaf or growing shoot, germinate in the same manner as the summer spores and give rise to a new generation of Oidium.

The perithecia do not all emit their spores at the same time owing to the different conditions of the places in which they have passed the winter. Some may even remain in the soil until the following spring. Perithecia have been shown to contain spores capable of germination eighteen months after their formation.[1] It is therefore impossible to completely exterminate the fungus in a vineyard in one year, however thorough the treatment. Burying the perithecia by plowing-in simply aids in their preservation and they are ready to cause a new infection two years later when brought to the surface again by later plowing. Although the Oidium was introduced into Europe as early as 1845, it was not until 1892 that the winter form of the fungus was found there. It was for this reason uncertain until that time that our Oidium and that of Europe were identical.

It seems probable that the fungus, under some conditions, can pass the winter in the conidial or summer form. At all events, in certain districts the perithecia have never been found and are therefore absent or very rare. They are very rare in the interior valleys of California. On the other hand, they are produced in immense numbers on vines within the influence of the summer ocean fogs. At Berkeley it is common to find thousands of them on every leaf and cane of a vine. More than 100,000 perithecia have been counted on the upper surface of a

[1] Revue de Viticulture, No. 655, p. 9.

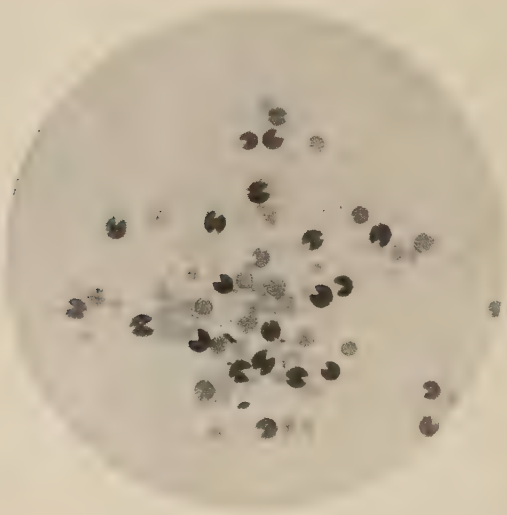


Fig. 7. Photomicrograph of Perithecia taken from Vine Leaf; magnified 30 times. The light colored bodies are immature *perithecia;* the dark colored, mature *perithecia* which have been burst open by pressure.

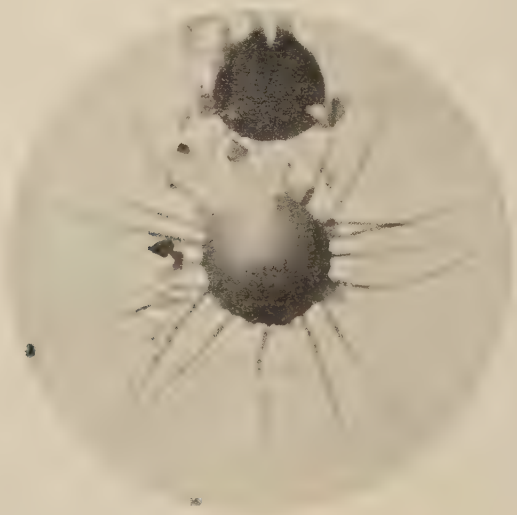


Fig. 8. Photomicrograph of Perithecia magnified about 200 times. One *perithecium* has been broken by pressure and the *asci* are partially pressed out. The winter spores can be seen through the transparent walls of the *asci.*

single leaf, and as each perithecium contains fifty or more spores, the number produced on a single vine may be hundreds of millions.

In Europe they are formed in September and October. In Berkeley they are found in abundance as early as the middle of June. Their formation seems to depend on weather conditions. If after a period of warm, moist weather, which has produced an abundant growth of mycelium, the temperature suddenly falls to near the lowest limit for the growth of the fungus (50° F.), they are produced rapidly and in great numbers. These are weather conditions which often occur at Berkeley and in the valleys nearest the coast.

In the interior very different conditions exist. The fungus may grow abundantly during the spring and early summer, but there is seldom any fall of temperature at this season sufficient to cause the production of the winter spores. As the summer advances, the air becomes too hot and dry for the fungus, so that by the time the cooler weather of October arrives, most of the Oidium has disappeared and the abundant growth of strong mycelium which is necessary does not exist.

CONDITIONS FAVORING THE DISEASE.

Variations in Susceptibility of Varieties. There is considerable difference in the susceptibility of various varieties of vines and therefore in the ease with which they can be kept free from the disease. All species of American vines,—Labrusca, Riparia, Rupestris, etc.,—are much less severely attacked than the European varieties of Vitis vinifera.

Among the latter there exist, however, various degrees of susceptibility. Of the varieties cultivated in California, those most easily and severely attacked are the Carignane, Flame Tokay, Muscat of Alexandria, Gutedel, Cabernet, Riesling, Clairette, Folle blanche, Ugni-blanc, and Petite Sirah. The more resistant are the Beclan, Duriff, Malbec, Mataro, Grenache, Alicante Bouschet, Petit Bouschet, Aramon, Mourastel, Vernaccia, and Marsanne. All varieties, however, are capable of being severely injured if the weather conditions favor the growth of the fungus. The Beclan and Duriff are perhaps the most resistant of all mentioned and are for this reason very valuable varieties to plant in localities within the influence of the summer ocean fogs.

Temperature and Moisture Conditions. The fungus requires certain degrees of temperature and moisture for its development. It grows most vigorously and abundantly in sheltered shady positions.

For this reason, vines on walls or trellises are more liable to attack, while vines out in the open vineyard, especially where they are subjected to the full action of the wind, are less severely affected.

Though the fungus requires less moisture than most others causing diseases of the vine, it will not grow in an atmosphere that is too dry. In the drier regions of California it is much less frequent than along the coast. Vines in low places or near the banks of rivers or irrigation canals are often attacked when the rest of the vineyard is free. Rains or fogs in the spring or early summer are very favorable to the growth of Oidium, especially if they are accompanied by a warm temperature.

The fungus will grow at a wide range of temperature. Below 50° F., however, its growth is arrested and for 15 or 20 degrees above this its growth is slow. Above 75° F., its growth is rapid and reaches its maximum at about 90° F. or 95° F., providing the air remains sufficiently moist. At about 100° F. it ceases to grow and at few degrees above this it is killed.

These considerations explain the different ways in which the fungus attacks vines in different localities and in different seasons.

In the *coast regions,* during the spring, the Oidium attacks most severely the outer leaves and the ends of shoots on the south and east sides of the vine. The parts of the vine which are shaded do not become sufficiently warm for the growth of the fungus. As the season progresses and the temperature of the air rises, the west and north sides of the vine become affected and finally, by midsummer, the fungus is able to grow on all parts of the vine and the bunches and bases of the canes are attacked. Very near the coast all parts of the vine are liable to attack throughout the summer, but in the main coast valleys, the fungus is usually confined to the interior of the vine after the middle or end of June.

In the *interior valleys,* it is very unusual to find the outer leaves of the vines attacked at any season. Vines which are much shaded by neighboring trees or buildings, however, may be attacked in the late spring in a way similar to that which occurs nearer the coast. Usually the fungus is first seen at or just before blossoming time and its attacks are confined to the canes, flower bunches, and interior leaves. This early attack sometimes causes a great loss of crop even when to a cursory examination the vine appears perfectly healthy.

During the summer, the dry air and great heat prevent the development of the fungus, and in fact destroy the greater part of it. The crop, however, may be seriously injured before sufficiently hot weather arrives. Most varieties of grapes in the hotter parts of the Sacra-

mento and San Joaquin valley will ripen their fruit perfectly if they escape the spring infection. Late ripening varieties, however, such as some of the table grapes, may be attacked during the cooler weather of autumn and in some seasons any variety growing vigorously in moist places may be attacked during summer and autumn.

CULTURAL METHODS OF CONTROL.

The Oidium can be checked to some slight extent by cultural methods. Anything which permits the sun and air to get to all parts of the vine more completely will lessen the danger from mildew. Rows of trees which shade the vines on the south side can often be removed with advantage. Vines planted wide apart are less subject to the disease, as they dry off more quickly in the morning. For the same reason, the rows of trellised vines should run north and south in order to facilitate the drying action of the rising sun. Low trellised vines are often less subject to Oidium than ordinary vines, as the foliage is spread over a larger surface and not massed around the head as in vase pruning. On the other hand, high trellised vines are usually more subject, as the wind and sun do not penetrate them so well.

Drainage of the wet places in a vineyard and methods of pruning and training which spread the vine out so that no part is surrounded by still moist air will tend to diminish the intensity of the disease.

SULFUR TREATMENT.

Mode of Action. No cultural method is capable of completely protecting the vines from Oidium except under the most favorable conditions and with the most resistant varieties. Some special treatment, therefore, is nearly always necessary. Of all the methods tried, there is none so effective as the dusting of powdered sulfur over the vines.

Sulfur acts by means of the fumes it gives off when the temperature is sufficiently high. These fumes destroy the mycelium and summer spores of the fungus, and if present in sufficient abundance will destroy every vestige of Oidium in the vineyard with the exception of the perithecia.

The exact nature of the fumes given off is uncertain. Some authors believe them to consist of sulfurous acid gas identical with that produced by the burning of sulfur and to be due to slow oxidation. The odor perceptible on a hot day in a sulfured vineyard, however, has not the pungent nature characteristic of the fumes of burning sulfur, but resembles that of hydrogen sulfid, which other authors believe to be

the active substance. Other investigators claim that the active fumes are simply vapors of pure sulfur volatilized by the high temperature.

The active fumes, whatever their nature, are given off in effective quantities only after the temperature of the air reaches about 75° F. Above this point they are given off the more actively the higher the temperature. Below 75° F. the fungus grows very slowly and the sulfur fumes are little needed, and, as the air warms up to a temperature at which the fungus grows rapidly, the fumes are given off in greater abundance.

The lower the temperature the more slowly the fungus is affected. If the highest shade temperature of the day is between 75° and 80° F., it will require from seven to eight days to destroy all the mycelium. When the temperature rises to 90°–95° F., the fungus commences to show signs of injury in 24 hours and in four or five days is destroyed. If the thermometer rises to above 100° F. in the hottest part of the day, one or two days are sufficient to completely rid the vineyard of the disease.

In order to obtain these perfect results, however, the sulfur must be applied to every part of the vine. The nearer a spore or a piece of mycelium is to a particle of sulfur, the more quickly it is killed. Except in the hottest weather, the sulfur on one leaf is almost without effect on the fungus on a neighboring leaf. The utility, indeed the necessity, of a perfect distribution of the sulfur, especially in comparatively cool weather, is apparent.

The air is always hottest near the soil, and sulfur placed on the soil should give off more abundant fumes. Practice has shown, however, that sulfur placed in this position has almost no effect on the Oidium except in extremely hot weather. In such weather, sulfur is hardly ever needed in California, as it is usually accompanied by such a dry condition of the air that the fungus is killed without the aid of sulfur fumes.

In exceptional cases, as for instance where very vigorous vines are growing in very moist places in the irrigated regions or when unusually hot weather occurs in the coast regions, the air may be moist enough for the growth of Oidium even when the temperature rises to considerably above 100° F. In such cases it is sometimes desirable to sprinkle the sulfur on the ground instead of on the vines. The reason of this is that if the air is sufficiently hot the sulfur may injure both the fruit and the leaves of the vines. The fruit and leaves may be spotted and, in severe cases, may fall completely or in part. Such effects are to be feared, however, only when the temperature exceeds

110° F., or with varieties particularly susceptible to sulfur fumes, such as Isabella, Othello, and certain other American varieties and hybrids.

If the earlier sulfurings are done properly, however, it will seldom be necessary to treat the vines in such weather and we may consider that the sulfur which goes on the ground is almost completely wasted.

Effects of Sulfur on the Vine, Fruit, and Wine. The effect of sulfur on the vine is in no way injurious except under the conditions already noted. On the contrary, most observers concur in noting improvement in the health and vigor of the vines after sulfuring irrespective of the control of mildew. Whether this is due to some stimulating action of the sulfur on the foliage or to its action on the plant food in the soil is in doubt.

The favorable influence of sulfuring the vines, while in blossom, on the setting of the fruit is even more generally recognized. If Oidium is present, this is easily accounted for by the prevention of the action of the fungus on the blossoms. The effect, however, is noticed even when no Oidium exists in the vineyard. The tendency of many varieties to "*coulure*,"—dropping their blossoms without setting,—can be lessened by vigorous sulfuring during the blossoming period. Whether this is due to a stimulation of the floral organs under the action of the sulfur, to the destruction of unrecognized fungi on the blossoms, or merely to the mechanical action of the current of air produced by the blowers in promoting pollination has never been determined.

Heavy, late sulfuring may introduce notable quantities of sulfur into the wine. This sulfur is apt, under the influence of the yeast, to give a disagreeable odor of sulfureted hydrogen to the wine. This odor is usually temporary and disappears after a few rackings of the wine. When the sulfuring is done with a suitable machine, however, so little sulfur is placed upon the grapes that this danger is not to be feared.

Properly sulfured vines ripen their grapes from 7 to 10 days earlier than those attacked by Oidium. This is probably due to the better health of the vines, which allows the fruit to develop more quickly and more perfectly.

Proper time and Weather for Sulfuring. The time of day at which the sulfur is applied is of little importance, provided the weather is suitable. It may be applied when the leaves are dry or when they are moist with dew. It is less effective, however, if the leaves are very wet, as the drops of water have a tendency to gather the sulfur into patches and leave parts of the leaf untreated.

It is impossible to do the work perfectly in a high wind, but a gentle breeze is an aid in making the sulfur penetrate to all parts of the vine.

Rain or very heavy and continued winds following immediately after the sulfuring will remove most of the sulfur before it has produced the desired effect on the fungus, and the treatment must be repeated. Each sulfuring should be followed by from one to four days of warm weather before the sulfur is removed by rain or wind. One or two days at or about 90° F. to 95° F., maximum shade temperature, or four or five days between 85° F. and 90° F. will usually give satisfactory results. If rain comes before the sulfur has been subjected to such temperature, the vines must be resulfured.

As already noted, sulfuring in excessively hot weather should be avoided on account of the danger of burning grapes or foliage. For the same reason, any cultivation or other disturbance of the vines should be avoided in hot weather immediately following the application of sulfur.

Proper Season for Sulfuring. The proper season for sulfuring will depend on the number of sulfurings needed. This number will differ according to locality, weather, variety, and the exposure of the vineyard and will vary from *one* to *three* in the *interior valleys* to from *two* to *five* in the *coast valleys,* or even as high as six or seven with susceptible varieties, in bad seasons in close proximity of the coast.

The most necessary and effective sulfuring of all, and one which should never be omitted under any conditions, is at the time when the vines begin to open their blossoms. Even with the most resistant varieties, in the least affected districts, this sulfuring should be applied. Even where there is little or no danger of Oidium, the gain in better setting of the fruit has been so frequently demonstrated that it amply repays the outlay. As all varieties do not blossom at the same time, the mixing of varieties in the same block should be avoided, for this and other reasons.

Number of Treatments. In the *interior,* if this sulfuring were regularly and universally applied, it would usually be sufficient. As many growers totally neglect sulfuring, however, there is danger of reinfection from neighboring vineyards during the early summer. The vines should be watched, therefore, and upon the first signs of Oidium, a second sulfuring should be applied. This will usually be at the time the grapes are about the size of buckshot. Later than this there is little danger usually, as the air becomes too hot and dry for the growth of the fungus. The vines should be watched, however, especially those

in moist parts of the vineyard—near irrigation ditches or in the shade of trees. Very vigorous vines or susceptible varieties in cool seasons also may exceptionally require another sulfuring just before the grapes commence to color or to soften. These late sulfurings, however, are dangerous in the hot districts for reasons already given, and can nearly always be avoided if the earlier treatments are applied properly and in time.

There are cases where it is advisable even in the interior to give the vines a sulfuring before the blossoming time. If the vines were badly attacked during the previous season there will be an abundance of spores in the vineyard and much injury may be done before the blossoming time if the spring is warm. In such cases, it is best to give an early sulfuring at the time the vine shoots are about 6 to 8 inches long. For this sulfuring it is very necessary to choose suitable weather. If unfortunately this treatment is followed by rain or continued heavy winds without any intervening warm days, it should be repeated.

This early sulfuring is very useful also in destroying the mites causing *erinose*,[1] a disease which often does considerable damage to the vines before the weather is warm enough for very rapid growth of Oidium. The erinose attacks with particular intensity Mission and Flame Tokay.

In the *coast valleys*,—Sonoma, Napa, Santa Clara, etc.,—two sulfurings should always be given; the first at the time the shoots are from 6 to 8 inches long. This treatment might be omitted in dry, well ventilated situations with resistant varieties, if sulfuring were universally practised throughout the district, but it is at present always safer to apply it. The second sulfuring should be at blossoming time. In dry early summers, except with the most susceptible varieties such as Carignane, a third sulfuring will often be unnecessary. The vine should be carefully watched, however, and, on the first appearance of mildew, sulfur applied again. In bad seasons a fourth sulfuring just before the commencement of ripening may be necessary. By watching the parts of the vineyard which experience has shown to be the most quickly affected, it is always possible to control the disease before it has done any serious damage.

After the grapes have commenced to ripen, they are almost safe from the attacks of Oidium, but it is a mistake for this reason to allow the fungus to become abundant on the leaves, as it may in warm, moist autumns. Though such a late attack may do little or no damage to the

[1] See Bulletin No. 136, "The Erinose of the Vine."

current crop, it will injure the buds and canes on which the crop of the following year depends. Moreover, it is this late growth of mildew which produces the winter spores and promotes an early and severe attack of the disease during the following spring. The vines therefore should be kept free from Oidium even if it requires a sulfuring after the grapes are gathered.

In the coast districts where weather conditions similar to those of Berkeley exist, even three sulfurings will seldom be sufficient to hold the Oidium completely in check. Where the springs are warm and the summers comparatively cool and moist, as along the coast of Santa Cruz, the fungus finds conditions favorable to its development at all times of the year when the vines are in leaf. In such locations an early sulfuring, when the shoots are 3 or 4 inches long, another at blossoming and a third when the grapes are the size of buckshot are always necessary. If these are thorough and there are no neighboring neglected vineyards to spread continuous reinfection, certain varieties may be kept free in good years by three sulfurings. It will, however, usually be necessary to interpolate another treatment between the first and that at blossoming time and follow the third with one or two supplementary treatments.

Sulfuring Young Vines. Young vines, whether in the vineyard or the nursery, should not be neglected. In the nursery they are peculiarly susceptible owing to their nearness to each other and to the moist air near the irrigated soil. Autumn sulfuring is nearly always useful in this case to keep the leaves healthy until they have ripened the canes. Young vines during the first year in the vineyard are seldom seriously injured by mildew, but it is advisable to sulfur them at least once during the early summer.

Methods of Applying Sulfur. From what has been said of the action of sulfur on the fungus, it is clear that thorough distribution is the main factor in its effective application. Providing we get some sulfur on every part of every vine in the vineyard, the amount we use is of little importance in controlling the disease.

Whatever the fumes may be which are given off, the amount of sulfur used in producing them is infinitesimal. The smallest quantity of sulfur we can possibly use in practice is amply sufficient if we accomplish the object of *leaving no part of the vine untouched.*

On a properly sulfured vine the distribution is so perfect that on close examination we are unable to find a square inch of surface free from sulfur grains. On the other hand, if on looking at a vine from a distance of twenty feet we can see any signs of the sulfur applied, more than enough has been used.

If the distribution is defective, we not only fail to free all parts of the vine from the Oidium but we leave enough of the fungus to spread rapidly through the vineyard as soon as the sulfur has been removed by rain or wind. Two or three incomplete sulfurings which fail to reach a number of whole vines or parts of vines are often less effective than one thorough treatment which leaves no part of any vine untouched.

The methods used in California for sulfuring vines are the following:

1. Throwing the sulfur on the vines by hand;
2. Distributing by perforated cans of various forms;
3. Shaking through the tissue of a cloth sack;
4. Various forms of hand bellows;
5. Various forms of knapsack bellows;
6. Traction sulfur distributers.

The disease can be completely controlled by any of these methods. They differ only in the amount of labor, sulfur, and care necessary in applying them. In these respects, however, they differ very notably.

1. Throwing on by hand is undoubtedly the most laborious, disagreeable, and wasteful. Something like 90 per cent. or more of the sulfur is wasted because most of it goes on the ground, and of that which goes on the vine a few leaves usually receive the bulk. When the vines are large, if all parts of the vine, extremities of canes and center of head, are properly treated, from five to twenty times as much sulfur will be used as by the best methods. It also requires more time than the better methods. It is moreover very difficult to get men to sulfur effectively by this means owing to the large amount of sulfur they get into their eyes and mouths. They are naturally apt to think more of protecting themselves than of destroying the mildew.

2. Distribution from perforated cans is perhaps the commonest method of application. It is a little better than hand throwing, but wastes a great deal of sulfur. With large vines from five to ten times as much is used as is necessary. It is very difficult to reach the tops of high vines with the ordinary forms of cans. Some sulfur cans are made with a long handle, which obviate this defect to some extent but increase the difficulty of sulfuring the low parts and center of the vine.

In both these methods it is unnecessary to use the best brands of sulfur, as with complete distribution so much is used that there is always enough fine material, except with the worst grades, to do the work. Some growers mix the sulfur with lime, ashes, road dust, or some inert powder to save sulfur. The main objection to this is that it involves the carrying and distribution of useless material.

3. An improvement on the last method is the use of a sack from which to shake the sulfur on to the vine. This sack should be made of cloth whose texture is close enough to permit only fine particles of sulfur to pass, but not so close as to require too much labor in shaking out the required amount. A sack about 14 inches long and 5 inches in diameter, holding about 3 pounds of sulfur when half full, is a convenient size. Somewhat tightly woven grain sacks of good quality are suitable material from which to make them.

Very good work can be done with sacks of this kind while the vines are small. Their main defects are that they hold very little and much time is wasted walking to the sulfur supply to fill them. They wear out very quickly and the work with them is laborious. They cannot be used while the vines are wet, as moisture on the sacks prevents the sulfur from coming out.

For large and high vines they are even less suitable than the cans. It is almost impossible to sulfur any part of a vine higher than the workman's head.

4. The use of small hand bellows similar to that shown in fig. 9, *b* is a great improvement over the three methods just described. The distribution of the sulfur is much better, the workman less troubled by the sulfur, and every part of the vine can be reached.

The main defects of these bellows are that they are very tiring to the hands and arms, and as they hold little sulfur much time is wasted in filling them. While not so wasteful of sulfur as the above methods, they use more sulfur than is necessary.

5. The best knapsack bellows are a great improvement on the hand bellows. These machines are known as "dust sprayers," "sulfuring machines," etc.

There are several hand "dust sprayers" of American manufacture which were originally designed for the distribution of paris green. The current of air by which the powder is blown on to the plant is produced by a rotary fan. The powder is stirred by various devices in the different machines and blown out of a reservoir through a tin or rubber tube.

The machines made in Europe specially for the distribution of sulfur differ from the above principally in the method of producing the current of air. This is produced by a valve bellows similar in principle to the old-fashioned blacksmith's bellows.

All the available American machines and one of the best European machines were tested this year by the Experiment Station. None of the American machines was found suitable for the purpose. They were

Fig. 9. Various forms of Hand Sulfur Distributers.

a, Upper left hand, European machine. *b*, Upper right hand, sulfur bellows. *c* and *d*, Lower figures, American machines.

nearly all extremely cumbersome and wasteful of sulfur. The best of those tested is shown by the photograph of fig. 9, *d*. They all have several very serious defects for the purpose tested. The regulation of the flow of sulfur is very imperfect and it is necessary to use an unnec-

essarily large quantity in order to cover the whole vine. This is especially true in the case of high vines. The machines worked fairly well only when the outlet tube was held in a downward direction. While treating the tops of high vines the sulfur accumulates in the tube, which finally chokes up. In order to clear the tube it is necessary to hold it down, upon which the accumulated sulfur runs out and is wasted on the ground.

The European machine, on the contrary, gave most excellent results. (See fig. 9,*a*.) The regulation device enables the operator to govern the amount of sulfur blown out with great precision. This is a very

Fig. 10. Sulfur cloud to cover the whole vine.

important point, as it makes it possible to use various grades of sulfur effectively and economically. The reservoir of the machine holds enough sulfur to treat two or three acres without refilling, but is less fatiguing to carry than the other machines, which hold only one-quarter as much. The sulfur is blown out in a fine impalpable powder (see figs. 10, 11, and 12), and owing to the form of the machine it can be applied to any part of the vine. By standing a little distance from the vine a single puff can be made to distribute the sulfur over the whole exterior of the vine. (See fig. 10.) Then after poking the end

of the tube into the center of the vine another puff will thoroughly sulfur the interior. (See fig. 11.) By a small attachment placed on the end of the tube the cloud may be forced upwards and the under side of the leaves more thoroughly treated (see fig. 12), but this is seldom necessary. The work is much less laborious than with any of the other methods tried and the workman is less liable to be troubled by the sulfur getting into his eyes.

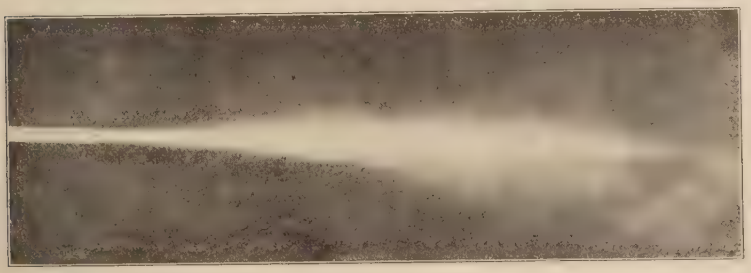


Fig. 11. Sulfuring interior of the vine.

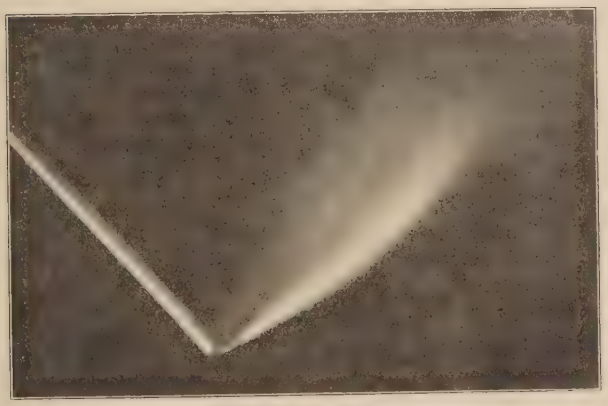


Fig. 12. Sulfuring the under side of leaves.

A machine made in San Francisco on the plan of the European machines was found excellent in all respects except that it lacked the regulating device.

The following table shows some of the results obtained with the various methods of sulfuring:

SULFUR AND TIME TAKEN TO SULFUR 500 VINES (1 ACRE).

Method	2 year old Vines		3 year old Vines		4 year old Vines	
	lbs. of S.	time: min.	lbs. of S.	time: min.	lbs. of S.	time: min.
A	4.82	30	------	------	8.4	56
B	8.61	30	------	------	11.1	63
C	6.56	33	12.7	56	------	------
D	9.84	30	------	------	23.9	65
E	9.43	33	28.6	60	------	------
F	6.56	33	28.9	58	------	------
G	12.30	30	42.8	69	------	------

A. European knapsack bellows. (Fig. 9, *a.*)
B. San Francisco knapsack bellows.
C. Hand bellows. (Fig. 9, *b.*)
D. American dust sprayer (the best of those tested). (Fig. 9, *d.*)
E. Sulfur sack.
F. Perforated can.
G. Hand distribution.

Each of the results given in the above table is the average of four tests made by four men and may be accepted as accurate so far as the amounts of sulfur are concerned. The time given for sulfuring, however, is less accurate. The four men doing the sulfuring worked together with different machines, so there was a tendency for the man with the most laborious machine to work harder to keep up with the others. This makes the difference in time between the various methods less than it would be in practice. No account, moreover, was taken of the time needed to go for sulfur and to fill the machines. This would still further increase the differences in time.

In all the tests made, the vines were given as complete a sulfuring as was possible with the means employed. A fair sample of sublimed sulfur was used.

ESTIMATE OF COST OF SULFURING 500 MATURE VINES.

Method	1st S. lbs.	2nd S. lbs.	3rd S. lbs.	Total S. lbs.	Cost of S.	Labor at $2 per day	Total cost
European machine	5.0	7.5	10.0	22.5*	.56	.60‡	$1.16
Hand bellows	7.0	13.0	20.0	40.0†	.80	.60	1.40
Dust sprayer	10.0	20.0	30.0	60.0†	$1.20	.60	1.80
Perforated can	7.0	30.0	50.0	87.0†	1.74	.60	2.34
Hand distribution	12.0	40.0	75.0	127.0†	3.54	.60	4.14

* Sulfur of good quality at $2.50 per 100 lbs.

† Sulfur of medium quality at $2 per 100 lbs.

‡ The time required will vary from three-quarters of an hour to one and one-half hours per acre (500 vines), according to the size of the vines and the method used. An average of one acre an hour is taken for the three sulfurings for all the machines. In practice it would probably be less than this for the best machines and more for the inferior methods.

The above estimates are based on the tests made,—tests which proved effective in completely controlling the disease. The amounts indicated for an acre when the European machine is used are less than is recommended by the best authorities in the south of France. Viala in "Les Maladies de la Vigne" gives 15-30-40 kilos as the amounts to be used for the three sulfurings of an hectare. This corresponds to about 75 pounds to the acre. The vines in the south of France, however, are planted much closer than ours, usually about 1,800 to the acre. The amount for 500 vines therefore would be a little less than our tests indicate.

Cost of Treatment. The total cost for sulfuring, including material and labor, will vary, if the best hand machine is used, from about 50 cents per acre for one treatment in the interior to $1.25 for three treatments in the coast valleys, or $2 to $2.25 for five treatments in the most affected localities.

Power and Traction Machines. No machines of this description have been tested by the Experiment Station for the sulfuring of vines. In Europe it is only lately that they have been used at all. The difficulties attending the distribution of large quantities of sulfur in a fine cloud by means of a current of air are very great. It is claimed by the manufacturers of several machines that these difficulties have been overcome, but the machines are very costly.

Moreover, it is hard to conceive of a machine which would do the work effectively without wasting a large part of the sulfur. When the vines are small, if the sulfur were thrown over a large area, as much would go on the ground as on the vines. As the vines when they first start cover only from 5 per cent. to 10 per cent. of the area, the amount of sulfur used by the power machine would be from ten to twenty times times as much as is necessary. As the cost of sulfur and of labor are epproximately equal with the best knapsack machine, no saving in cost of labor would offset this waste of sulfur.

When the vines are large it is doubtful whether any machine could throw the sulfur as effectively into the interior of the vine where it is most needed as can be done with the tube of a knapsack machine.

There is one consideration which makes it seem possible, however, that an effective power machine might have its uses here. There is nothing more expensive than losing the crop, and a power machine might make it possible to sulfur a vineyard and save the crop when it was impossible to have the work done by hand. Even at an extra cost of several dollars per acre this of course would be an advantage.

Quality of Sulfur. Any kind of sulfur in the condition of a pow-

der will control the disease if used as directed. Coarse powders, however, must be used in much greater quantities and are more difficult to apply properly. The absolute purity of the sulfur is of little importance, provided there is no large adulteration with inert and useless substances such as gypsum.

Many samples of sulfur were received at the Experiment Station during the past year and examined. Most of these samples were sent by grape growers. They were all found to be practically pure and unmixed. In the important matter of fineness, however, they differed widely. Two or three of them were so coarse as to be almost valueless for sulfuring vines. (See fig. 16, Sulfur No. 8.) A few were very good and most of them were passable. The prices quoted by the senders were little indication of the value of the samples. Some of the cheapest were of excellent quality for the purpose (see fig. 15, Sulfur No. 16), and some of the most expensive were among the worst (see fig. 16, Sulfur No. 8). This shows the need of a careful examination before purchasing.

Some of the results of our examinations are shown in the following table:

SAMPLES OF SULFUR RECEIVED AND EXAMINED BY THE STATION IN 1906.

No.	Price	C	
30	.....	66.8	Sublimed, very fine, no coarse material.
22	.....	60.8	Sublimed, very good, very little coarse material.
3	$52.50	60.0	Sublimed, very good, some coarse material.
20	45.00	58.8	Sublimed, very good, some coarse material.
19	70.00	52.0	Sublimed, good, but with many large grains.
28	41.00	50.8	Sublimed, good, but with considerable coarse material.
26	.....	50.0	Sublimed, good, but with considerable coarse material.
15	.....	49.2	Sublimed, good, but with some coarse material.
24	43.00	48.0	Sublimed, fair, about one-third of coarse material.
6	55.00	47.6	Sublimed, fair, but some coarse angular material.
29	60.00	46.0	Sublimed, fair, with considerable coarse material.
13	44.00	45.6	Sublimed, fair, with considerable coarse material.
18	———	42.8	Sublimed, with much medium coarse material.
4	55.00	40.0	Sublimed, with much coarse material.
16	32.00	51.6	Ground, good, with little coarse material.
31	.....	46.8	Ground, good, with about one-third coarse material.
23	.....	46.0	Ground, good, with about one-third medium material.
25	45.00	46.0	Ground, fair, about one-half fine material.
10	30.00	45.6	Ground, good, except for some large particles.
17	.....	45.6	Ground, good, but considerable coarse material.
5	40.00	45.2	Ground.
21	45.00	45.0	Ground, fair, about one-half fine material.
27	30.00	44.5	Ground, fair, about one-half fine material.
12	.....	39.6	Ground, much coarse material.
1	44.00	37.6	Ground, much coarse material.
7	45.00	37.6	Ground, fair, much coarse material.
2	47.50	37.2	Ground, coarse.
11	.....	36.0	Ground, poor, very little fine material.
14	.....	34.4	Ground, very poor, hardly any fine material.
8	47.50	34.0	Ground, principally large particles.

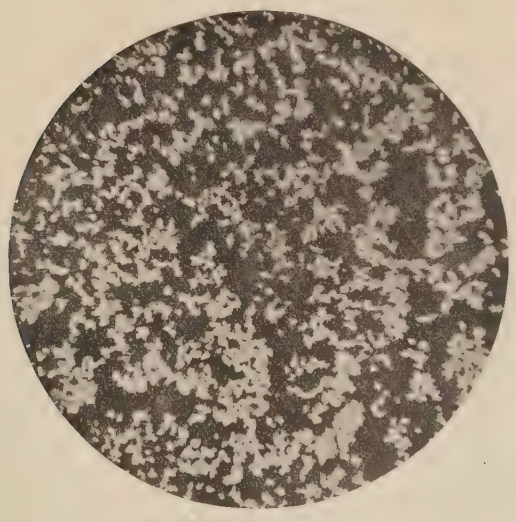


Fig. 13. Sublimed Sulfur of very good quality. Sulfur No. 30.

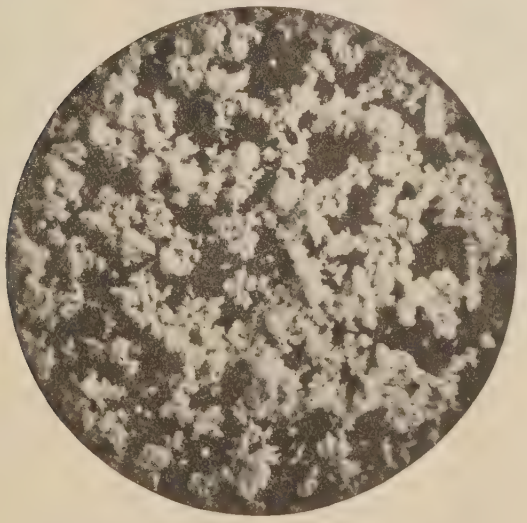


Fig. 14. Sublimed Sulfur of poor quality. Sulfur No. 4.

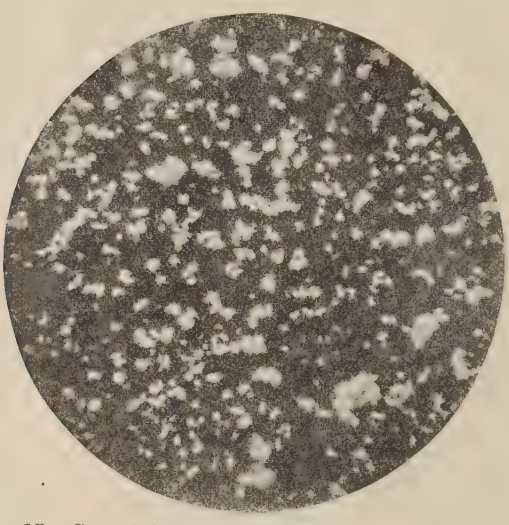


Fig. 15. Ground Sulfur of good quality. Sulfur No. 16.

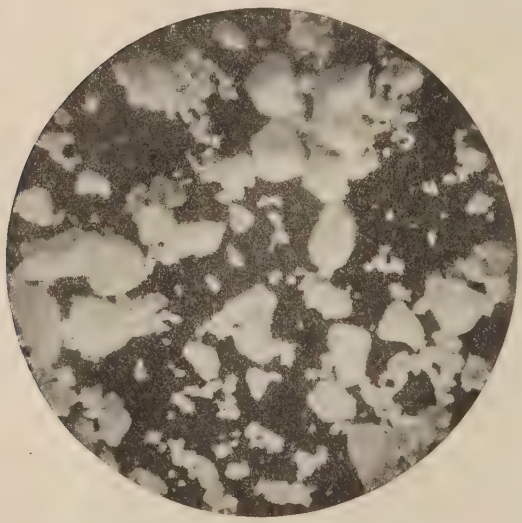
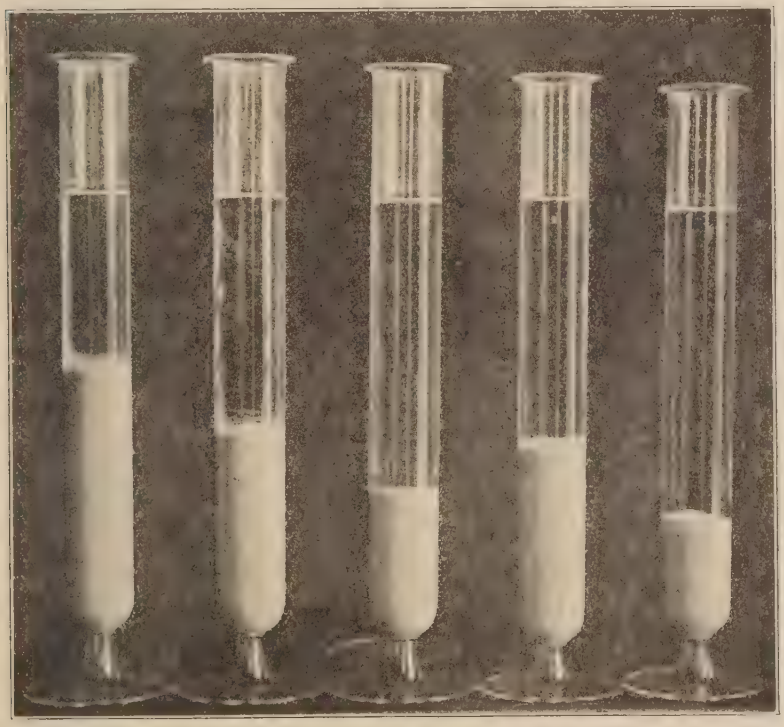


Fig. 16. Ground Sulfur of very bad quality. Sulfur No. 8.

The data given are the prices and the results of the Chancel test, column C, and of the microscopical examination. The Chancel test is the determination of the amount of settling that occurs when 5 grams of sulfur are allowed to stand in a cylinder after shaking up with 25 cubic centimeters of ether. The number represents the percentage of the height of the cylinder occupied by the sulfur after settling. It is a very convenient and quick method of testing the fineness of the sulfur. (See fig. 17.)



30 28 4 16 8

FIG. 17. Comparative volumes of 5 grams of different sulfurs.

No. 30.	Sublimed Sulfur, Chancel No. 66.8	$70.00
No. 28.	Sublimed Sulfur, Chancel No. 50.8	41.00
No. 4.	Sublimed Sulfur, Chancel No. 40.0	55.00
No. 16.	Ground Sulfur, Chancel No. 51.6	32.00
No. 8.	Ground Sulfur, Chancel No. 38.0	47.50

The numbers corresponding to good commercial sublimed sulfur are 50 to 70; those of the finest quality show 75 to 90. Powdered or

ground sulfur of the best quality will show from 60 to 70, and those of ordinary quality 43.[1]

All the sulfurs examined, with the exception of two of the ground samples (Nos. 8 and 14), contained sufficient fine material to do effective work, but the amount it would be necessary to use of the various grades would vary considerably. If the sulfur is applied by hand or with perforated cans, any of the sulfurs except Nos. 14 and 8 would probably be nearly equally good, and therefore the cheapest would be best. If we use several times as much as is needed, as we must with these methods, it matters little if 25 per cent. or 50 per cent. of the sulfur is useless.

When using an effective sulfur machine it is possible to utilize the superiority of the finer grades, and in this case it is undoubtedly advisable to use the better qualities. (See figs. 13 and 15.)

A few simple directions for the examination of sulfur may be of use to the grower.

1. The finer the sulfur the more bulky. Therefore if several sulfurs are in sacks of equal weight, the largest sack will contain the finest sulfur. A 110-pound sack of good flowers of sulfur is twice as large as a 110-pound sack of very coarse ground. The difference in bulk between equal weights of sulfurs of various qualities is shown in fig. 17, representing the Chancel test.

2. The color of sublimed sulfur is a clear, bright yellow. The color of ground sulfur will vary with the fineness. Coarsely ground sulfur is almost of the same color as sublimed. When finely ground, the color becomes whitish. The whiter a ground sulfur, the finer it is, provided the color is not due to adulterants.

3. A good sublimed sulfur should feel as soft as flour when rubbed with the fingers in the palm of the hand. If hard particles are felt, the sulfur is not of the best quality. Ground sulfur always feels a little gritty, but the hard particles should not be large or numerous.

4. A very good idea of the fineness of a sulfur can be obtained by the use of an ordinary good hand magnifying glass costing about $1. A magnification of 10 or 20 diameters is sufficient. With a little experience sublimed and ground sulfur can be distinguished by this means. The particles of sublimed sulfur are all nearly spherical with smooth outlines. Those of ground sulfur are irregular and with sharp edges.

The sulfur is most easily examined when spread on a piece of glass over a dark background. A good way to spread the sulfur is to place

[1] Viala, P., Les Maladies de la Vigne, p. 53.

a small pinch on the glass, wet it with a few drops of ether, and shake. This will distribute the sulfur in a thin layer over the glass and much facilitate the examination.

5. A test of the purity may be made by burning a pinch of the sulfur on a piece of white porcelain—a broken plate, for example. To make the burning complete, hold the piece of plate over a lamp or on top of a very hot stove. A pure sulfur burns away completely, leaving only a black stain on the plate. Any dust or particles that are left indicate adulteration.

The fine sulfurs are superior in three important respects: (1) They capable of more perfect distribution; (2) they offer a larger surface to the air and therefore give off more fumes; (3) they adhere better to the leaves.

A pound of a very fine sublimed sulfur such as No. 30 (see fig. 13), the particles of which measure .01 mm. in diameter, if evenly distributed and none lost, would give about 15,000 particles for every square inch of leaf and cane surface on an acre of large vines. A pound of a very coarse sulfur such as No. 8 (see fig. 16), the particles of which have twenty-five times as large a diameter, would supply only about one particle for every square inch. Moreover, a much larger proportion of the coarse sulfur would be lost by failing to adhere to the leaves and falling on the ground. Perhaps the most important advantage of the finest sulfur in this respect is that the impalpable powder floats so lightly in the air that it reaches and adheres to the lower surfaces of the leaves and canes. A finely powdered sulfur such as No. 16 (see fig. 15) would probably be just as effective as the sublimed, for though it contains a certain proportion of coarser particles, the finer material has not the tendency to cohere in the groups of particles characteristic of sublimed sulfur.

The quantity of fumes given off by a sulfur must be about in the proportion of the extent of surface which the particles present to the air. This surface is inversely proportionate to the diameter of the particles. A pound of sulfur, No. 30 or No. 16, would possess a surface twenty-five times as great as that of No. 14, and would therefore give off fumes much more rapidly and in greater quantity.

OTHER METHODS OF TREATMENT.

Combined Treatments. Various other substances and sprays have been suggested and tried for the control of the Oidium during the growing season. There are two cases in which it has seemed desirable to attempt to find another method of control. One of these is where it

is necessary to treat for another vine disease which cannot be controlled by sulfur at the same time. In Europe, where spraying with copper solutions is necessary to protect the vines from Peronospora, Black Rot, and Botrytis, various sprays have been tried with the object of controlling the Oidium at the same time. These sprays are principally liquids containing Bordeaux mixture, copper sulfate, or sulfosteatite together with "wetable" sulfur. There is considerable uncertainty as to the success of these combinations, and as the diseases they are intended to reach do not exist in California they are of little interest to us.

The other case is where sulfur has been found ineffective or too slow in its action. This seems to be the case in the Eastern States, and may be in certain parts of the coast region of California or perhaps exceptionally in other regions in abnormal years.

Liquid Sprays. Dry sulfur to be effective requires warm weather. If the weather is cool its action is slow or nil. Certain sprays act immediately on the Oidium whatever the temperature. It should be remembered, however, that the Oidium grows very slowly or not at all below temperatures at which sulfur is effective. Cases, however, may arise where, through neglect of proper sulfuring, the vines may be badly attacked by mildew, and owing to the coolness of the weather when the trouble is first perceived sulfur may act too slowly. In such cases it may be advisable to use a quick acting spray.

Such a condition might occur in a cool late spring.

Another case in which a spray may be useful is where the vines have been very badly affected the previous autumn and the canes are covered with winter spores and perhaps hibernating mycelium ready to infect the new shoots on the first warm day. A spraying just as the buds swell might be of help in such a case.[1]

Spraying in the summer should never be necessary, as the heat is sufficient to cause the sulfur to act quickly. It has been suggested that late sulfuring is inadvisable because it may cause spotting of the grapes. If the grapes have not commenced to ripen this will not occur if the sulfur is applied properly, and if they have commenced to ripen they are safe from the disease, and sulfuring to protect the vines should be deferred until the grapes are gathered.

No sprays, however, do the work as thoroughly as sulfur. A spray only kills the fungus which it actually touches, and the most perfect spraying possible will leave some parts of the vine untouched. Where

[1] Tests of winter spraying by Pacottet and Ravaz in France gave no favorable results.

a spray is used it should therefore be followed by an application of dry sulfur to complete the work.

The sprays which have been found most effective for this purpose are Bordeaux mixture, permanganate of potash, and alkaline polysulfids. Vines are not easily injured by copper salts, so that a strong Bordeaux can be used. The 6–4–50 formula would be suitable.

Permanganate of potash at the rate of one pound to 100 gallons of water has been found effective. A little chloride of potash or common salt improves the spray by increasing its adhesive qualities.

Liver of sulfur at the rate of 4 pounds to 100 gallons of water with 4 pounds of soap has also been used with success. Alkaline polysulfids have also been used effectively in the same way. These sprays are more permanent in their effects than the copper and permanganate mixtures because a small amount of finely divided free sulfur is set free, which acts in the same way as the powdered sulfur when applied in the usual way. It is very probable that a weak lime-salt-sulfur spray such as is in common use on fruit trees would be equally effective.

WINTER TREATMENT.

As the fungus passes the winter, when it has no green leaves to grow on, in the form of resting spores on the canes and in the soil and perhaps of resting mycelium under the bud scales, it has been suggested that a winter treatment which would destroy these hibernating forms would be the best method of control, or at least that it would much simplify the summer treatment.

The methods usually proposed are to spray the vines after pruning with the lime-salt-sulfur used for fruit trees or with a 2 per cent. solution of bluestone. Others advise swabbing the vines at the same time with a saturated solution of iron sulfate (copperas) acidified with 1 per cent of sulfuric acid. To make the treatment more thorough, some remove all the dry bark of the vine by means of scrapers before treatment. This is supposed to destroy all the perithecia on the vine. In order to prevent infection from the hibernating mycelium under the bud scales it is further advised to spray the vines with Bordeaux mixture just as the buds swell in the spring.

Such treatments as these are of course very expensive and cost more than several sulfurings, so that, unless they can be proved to be effective, they should not be adopted. There is considerable evidence that such treatment makes the vines more vigorous and healthy, but that it has any effect on controlling the Oidium is doubtful. It seems *unnecessary*, because if we control the Oidium in the summer, as we

must do to save our crop entirely, there will be no winter spores formed and, therefore, no use in spraying for them.

Winter treatment, moreover, cannot be *completely effective* because, however well done, it cannot destroy all the resting spores, because most of them are in the soil, and if but a few escape, they are capable of infecting the whole vineyard when the weather conditions are favorable. Sulfuring, therefore, is necessary even when winter spraying is practised.

There is reason to believe, moreover, that winter treatment is *completely ineffective.* Every other vine in a small patch of vines at Berkeley was treated last winter with bluestone, iron sulfate, or Bordeaux mixture. In the spring just as much mildew was found, on its first appearance, on the treated as on the untreated vines.

A still more convincing experiment is described in the "Revue de Viticulture," No. 655, page 12. This seems to prove as well as a single experiment can: First, that the fungus does not pass the winter to any extent in the summer form under the bud scales; and second, that the most thorough winter treatment is useless if no winter spores are formed, and completely ineffective if they are.

Mr. Pacottet says in the article quoted: "In 1904 we observed that the spring attack of Oidium occurred first precisely in those hothouses of Nanterre where perithecia had been found in the autumn of the previous year. The same fact was observed in 1905. This led us to make careful observations the following year on the manner and time of the appearance of the Oidium.

"Oidium appeared at the end of March, 1906, and only in those grape houses, to the number of 20, where the presence of winter spores had been noted in November of the previous year. In these houses the fungus appeared with such intensity that nearly every leaf showed simultaneously several patches.

"These observations acquire especial importance when considered in connection with the various hypotheses which have been advanced regarding the modes in which the Oidium passes the winter, especially as regards the hibernating of fragments of mycelium (summer form) adhering to the canes and capable of vegetating anew in the spring.

"At Nanterre the disinfection of the vines is as complete as it is possible to make it. After removing the old bark they are treated with boiling water and swabbed with a 30 per cent. solution of iron sulfate. They are then covered with a paste of lime and sulfur. * * * Before the starting of the buds, the walls, glass, and casings are disinfected with strong washes and the air with the fumes of burning sulfur."

Now, even with such thorough winter treatment as this, which it would be quite impracticable to apply in a vineyard, no apparent effect was obtained in the control of the spring infection. The spring infection was due, therefore, to spores which were not on any part of the vine, and from which no kind of spraying or swabbing of the vine would be any protection whatever.

Pacottet concludes, therefore, that practically all the spring infection is due to spores which have passed the winter in the soil. These are the spores contained in the perithecia which have dropped in the autumn with the leaves on which they are formed. His advice for hothouse treatment is to gather all these leaves before they fall and to burn them.

This again is impracticable in a vineyard, and we are forced again to the conclusion that no form of winter treatment is of any use in the control of Oidium in vineyards, and that the only practicable method is proper sulfuring of the vines in spring and summer. This will prevent injury to the vines, and if thorough will prevent the formation of winter spores.

SUMMARY.

Oidium is one of the most serious diseases of the vine and the only serious fungus disease of vines in California.

It is capable of destroying the whole crop in most vineyards in bad seasons if not controlled.

Much more damage is done to vines and grapes in California than is usually supposed, but the control is much easier and more certain than in most vine-growing countries.

The disease attacks leaves, canes, and fruit during the growing season.

It grows only on the exterior green surfaces of the vine and passes the winter in the form of resting spores in the soil.

Certain varieties of vines are very susceptible and others comparatively resistant.

Moist warm atmosphere favors the growth of the fungus.

Methods of training, cultivation, and irrigation which keep the vine dry by thorough aeration minimize the danger of attack.

Dusting the vines with sulfur is the cheapest and most efficient method of control in California.

The weather and the season when the sulfur is applied are of great importance.

The number of treatments will differ with the locality, the season, and the variety of vine.

Vines should be protected from late attacks even after the grapes are gathered.

Young vines should be protected as much as old, even when they are in the nursery.

The usual methods of applying sulfur by hand or with perforated cans is wasteful and uncertain.

A good sulfur sprayer is essential for the best results. None of the American dust sprayers tried is suitable for the purpose. The "Vermorel soufreuse Torpille" was found to answer perfectly.

The cost of treatment, when a good sulfur distributer is used, varies from 50 cents to $2.25 per acre, according to the number of treatments necessary. The cost is about equally divided between sulfur and labor.

Traction machines do not promise any improvement in cost or efficiency.

Finely divided sublimed or powdered sulfur should be used. Coarse sulfurs cost more because more is needed and they are less effective.

No other form of summer treatment is so effective as sulfuring, but in rare, special cases a supplementary spray may be useful.

Winter treatment is in all probability of no use in the control of Oidium.

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